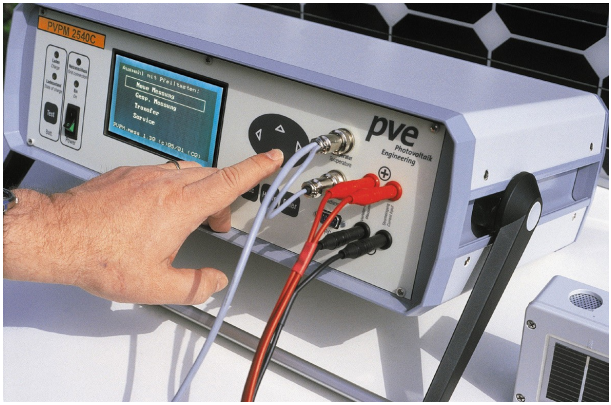
PVPM 2540C
6020C
1000C
1000C40

Peak Power Measuring Device for PV-Modules



Users Manual

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Iserlohn, 20.06.2003

2 Introduction

The devices of type PVPM enables the measurement of the I-V-curve of photovoltaic modules as well as of strings. By a new developed procedure the device can measure and calculate the peak power Ppk, the Rs and Rp directly at the place of assembly of the PV system. Calculation results and the diagram can be displayed on the internal LCD-display.

The peak power is the power of a module under Standard Test Conditions (STC) [1]. So far the very sumptuous measurement of the peak power was possible only in particularly suited laboratories. By a new procedure [2], which was developed by Professor Wagner at the University of Applied Sciences Dortmund (patented), the measurement with the PVPM can easily be performed. So the quality control of a PV system can be executed fast and economically. This simple and meaningful check in practice serves the certainty of the customer and also that of the installer. Beyond that the measured I-V-curves permit further explanations about the electrical characteristics of the verified module or string. So the PVPM is suitable as well as an instrument in research as for development purposes.

The PVPM is a mobile measuring device with integrated battery supply and battery charger in a durable metal housing. The device has its own industrial miniature PC and a high-contrast LCD display and thus its function is independent of other devices. However if desired a PC can be attached for data transfer and further analysis of the measured values over a standard interface.

The PVPM is operated comfortably over few keys and an on-screen menu. The functions are defined self-describing and the user is always led by the program. So no long training activities for the operating staff are necessary.

Description of the measurement

The PVPM automatically measures the I-V-characteristic of the generator at a capacitive load. From the measured data it calculates the effective solar cell characteristic, Ppk and Rs. [2], [3]. After the measurement the data are stored automatically in a non-volatile storage and so are available also later (e. g. in the office) [4]. The device internally stores the data of more than 100 measurements.

The following results are displayed:

Permanent values:

Peak Power PPk

Internal Series Resistance Rs

Internal Parallel Resistance Rp

Current values, depending on irradiation and temperature:

Vpmax , Ipmax , Pmax

Voc , Isc , FF, Tmod , Eeff

The determined I-V-characteristic can also be shown directly on the LCD display.

[1] IEC60904-3: STC= Irradiance 1000 W/m2, Spectrum AM=1.5, Cell Temper. 25°C

[2] Wagner A.: Peak Power and Internal Series Resistance Measurement under Natural Ambient Conditions. –EuroSun Copenhagen 2000

[3] Bendel C., Wagner A.: Photovoltaic Measurement relevant to the Energy Yield. - WCPEC3 Osaka 2003

[4] Schulte K.M., Wagner A.: Die Effektive Solarzellenkennlinie. - Anwendung Teillast-Berechnung. Staffelstein. 2002

3 Safety Requirements

Before the first use of the PVPM1000C read this manual carefully and completely. It contains important hints to avoid damage to persons or the measuring device. These hints are emphasized by a frame around the text and should be paid attention to.

The program *PVPM.disp* requires a PC with hard disk and MS Windows® 9x or NT® and a mouse device. The connection of the PVPM1000C requires a free serial interface. Please be sure that this interface has no interrupt conflicts with other devices in the PC.

The required free space on the hard disk before installing PVPM.disp is about 2 MB. Please be sure later on that there is enough room on the hard disk before storing measured data.

The program stores important values in a file named *PVPMdisp.ini.* Do not modify this file manually, this could affect the normal operation of the program!

Attention: For the purpose of data security we would like to point out the importance of saving the database of the program regularly on another data medium, so in the event of damage you will be able to continue working without considerable data loss. Such a damage can not be excluded even under the present state-of-the-art. Please do not restore single data files, but always the complete data back-up of the program, otherwise you might cause malfunction, this in turn might lead to data loss! In case of doubt please contact the distributer or the producer.

! WARNINGS !

To disregard the following information can lead to severe injury and even entail a peril to life

This device may never be utilised close to inflammable gases.

Keep children and infants away from the measuring equipment!

The measuring device may not be used in locations with intense dust exposure or high humidity. No fluids may reach the interior of the measuring device.

At appearance of unusual sounds, the development of smell or smoke the device has got to be switched of immediately, the circuit breaker and the current source have got to be disconnected.

If the conducting wires of the measuring device are damaged they have to be replaced. Mending the wires is not admissible.

The current measurement input may only be attached to a limited source of direct current (Photovoltaic-Generator) with at most 20A (40A with PVPM2540C)! The junction of other sources can lead to demolition of the device!

For security reasons only qualified personal must establish the cable connection between the PV generator and the PVPM security switch! The measurement should be carried out or

accompanied by qualified personal. Additional qualifications and laws (e.g. VDE 0100) have to be observed, otherwise high currents and voltages involve danger of life!

The PVPM1000C and all devices being part of it may be opened and repaired by authorized qualified personal only. Before opening a case every cable connection must be disconnected!

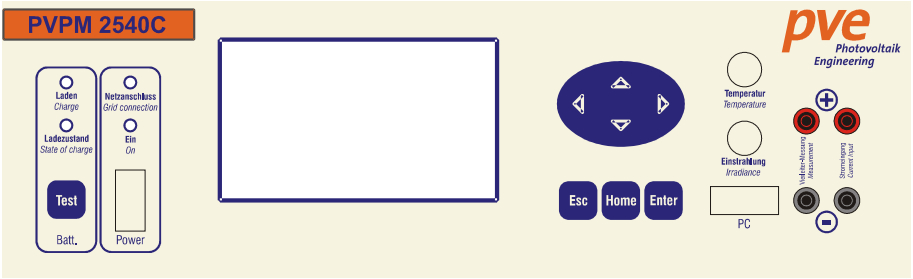
The solar generator possibly can generate very high tensions and currents, which can affect your health when you do not handle with care!

!! VERY IMPORTANT !!

Never plug in or remove the cable connectors between solar generator and PVPM1000C before the solar generator is deactivated! A security switch added to the measurement line allows the simultaneous disconnection and the safe connection of measuring wires to the PVPM.

The PVPM will make a short circuit during measurement or due to wrong polarization, and when you tear of a cable under this condition, a light arc can arise and can cause serious damage to health and material! After the generator is deactivated you can remove the cable connection without harm.

4 Operation of the PVPM1000C



4.1 General Hints

The PVPM1000C, as nearly all electronic measuring device, can only operate in a defined temperature range (see appendix). That is why the PVPM1000C should not be exposed to direct sunlight over a longer period. Keep the device in a shady place or protect it from direct sunlight using a sunshade.

The standard version of PVPM1000C can not be integrated into other devices or e.g. brackets. It is very important that the air can move free around the case so a proper cooling is guaranteed! Only if the PVPM1000C is completely out of operation (even no charging) it may be stacked.

Attention: Never loosen a cable connection during measurement! The considerable dc tensions and currents can cause a light arc which can be the reason for fire and serious injuries! (see chapter 3)

The front panel of the PVPM1000C is rather rough, but you should handle it with care anyway. To avoid damage of the front panel please take notice of the following hints:

- Do not touch the front panel with a sharp or pointed object. This could force scratches and might even destroy the foil especially in the regions with keys in the back.
- Clean the surface with a soft and not to wet tissue. Do not use materials that can scratch, especially on the cover of the display. A scratched display cover will dramatically affect the display quality.

The case is not water proofed. Do not expose the PVPM1000C directly to rain or similar influence.

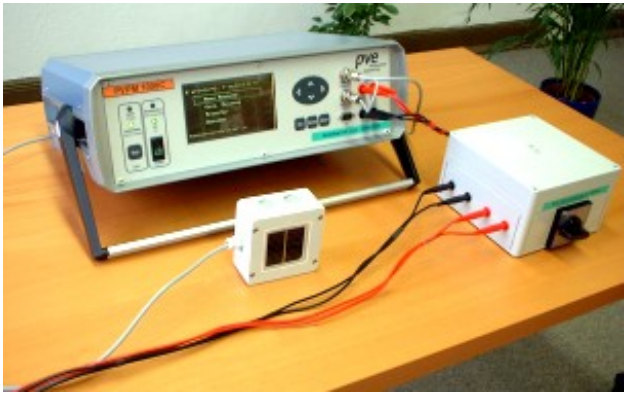
For a good measuring quality the sun irradiance during the measurement should be above 500 W/m2. Measurements are possible below this irradiance value, but less precise.

For the determination of Rs the two necessary I-V-Curves must be measured at different irradiances. The difference should be more than 10%.

4.2 Connecting Peripheral Devices

For a measurement the following components are necessary:

- Peak power measuring device PVPM1000C (measurement of I-V-curve, display of Ppk)
- Phox sensor with Pt1000 temperature sensor
- external security switch 1000V / 20A (see chapter 5)



- of course the module to be measured and the cable connection to PVPM1000C
- optional: External PC for the operation of the measurement and evaluation of the measured data

The PVPM1000C is equipped with the following input/output interfaces (you find all interfaces besides the grid connection at the front panel, they are all marked):

Interface	Function
Grid	At the back, connection to 230V/50Hz grid power
Temperature	Temperature sensor
Irradiance	Phox sensor
4-wire-measurement	Voltage input
Current input	Current input
PC	Connection to PC (AT Cross cable 9-Pin)
(LPT1)	optional: at the back of the case

Combined sensor

4.3 Power Supply

The PVPM1000C contains a accumulator which lets it become independent from grid power supply. The accumulator can be charged by the integrated charge unit. For this purpose you must connect the PVPM1000C to the grid power. After switching on the grid power on the back side of the case the accumulator is loaded automatically. The loading state is displayed by a LED at the front of the device.

4.4 Connecting a PC

The PVPM1000C can operate independent from a external PC. For an extended evaluation of the measured data or just for controlling the PVPM1000C from the PC you can connect the PC to the PVPM1000C: Put the delivered cable (SUB-D 9B / SUB-D 9B) to a free serial port of your PC and to the “PC” connector at the PVPM1000C.

Caution: before you can control the PVPM1000C from a PC with PVPM.disp it is necessary to select the menu option “transfer” on the PVPM1000C. Otherwise the PC can not access the device.

4.5 Connecting the Solar Generator

Important: during a measurement the solar generator to be measured must be disconnected from all other devices like batteries, inverters or loads. The PVPM1000C will make a short circuit to the solar generator for some seconds and it might be damaged by connected batteries or load capacities in the inverter!

Connect the measuring device properly to the solar generator using the cables delivered with the measuring device. The plus pole is marked RED, the minus pole is marked BLACK! When connected wrong (exchanged polarity) the solar generator is in short circuit through the in PVPM1000C integrated safety diodes (no measurement of current possible). This condition must not be kept for more than one minute, else the measuring amplifier may overheat.

it is important, that all 4 plugs of the 4-wire-measurement are connected properly by the delivered 4-wire-cable or (if you don’t want a 4-wire-measurement) the two red plugs should be connected and the two black plugs as well. Use short circuit plugs or laboratory cables for this purpose. Without this connection a measurement of voltage is not possible!

Caution: keep a sufficient distance to power leading parts of the cables between solar generator and measuring device. These cables may lead high tension what may affect your health even without direct contact!

4.6 Connecting the Combination Sensor

For a measurement you must connect a Pt1000 temperature sensor and a Phox sensor (delivered as a combined device) to the relevant plugs of the PVPM1000C. For the measurement of serial resistance Rs or I-V-curve only these sensors are obsolete. The plugs are build in a way you cannot connect a sensor to a wrong plug.

The combined Phox/Pt1000 sensor should be mounted near the modules to be measured. It must have exactly the same orientation (elevation and azimuth) re. the sun as the modules have. Most time the easiest way is direct assembly to the module frame. Please take care that the sensor will produce no shadow on to the module! The sensor needs several minutes to adapt to the environment conditions: the reference cell firstly must reach the temperature of the module, before you can make a measurement with the PVPM1000C (see chap.4.9).

4.7 Turning On

Turn the power of PVPM1000C on by pressing the switch “Power” on the front panel. The control lamp “On” will show you the presence of power from the accumulator or grid connection. The PVPM1000C will no pass some self tests and will need about 15 seconds of operation for readiness. The device is ready when the main menu appears on the LCD-screen.

Lamps on front panel:

Charge	Lights up, when accumulator is charged	
State of charge (3 color LED)	Red: Accumulator discharged (charge at once!) Green: Accumulator ready Yellow: Accumulator charged completely *)	Operation not possible! Operation possible Operation possible
Grid connection	Lights up, when grid connection (230V/50Hz) is connected and switched on	
On	Lights up, when PVPM1000C is operating (the readiness will be	

	displayed on the LCD display)

*) If the lamp alternated between green and yellow steadily the accumulator load is kept. This part of the loading should not be retained for more than 3 hours, because else the accumulator could be damaged.

The PVPM1000C reports several system conditions, functions and errors by speaker signals. A list of signals you will find in the appendix.

When the device signaled readiness, you can make a measurement.

4.8 Keys

4.8.1 Test

The “Test” key is used to visualize the load state of the accumulator with the front panel LEDs when the device is not operating. You should do this regular to avoid damage of the accumulator through inevitable self discharge. Charge the PVPM1000C completely at least once a month even if you don’t use the device.

4.8.2 ESC

The “ESC” key will bring you up to the next higher menu level.

4.8.3 HOME

The “HOME” key will bring you up to the main menu.

4.8.4 ENTER

With the “ENTER” key you select an option or confirm.

4.8.5 Arrow keys

You can move the mark in menus and other lists using the arrow keys.

4.9 Measurement

Please pay attention to the safety hints in chapters 3+4 and factors affecting measurement accuracy in chapter 5.

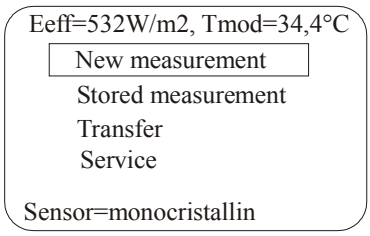
The measurement can be started from the PVPM1000C or from a connected PC (see chapter 8). The measurement should not be started before the solar generator and the necessary sensors are connected properly. The measurement will take about 2 seconds, than the calculated results will be displayed immediately on the PVPM display (or on the PC).

4.10 Menus

On the display of PVPM1000C you will find vertical and horizontal menus. The handling is same for both: choose an option with the arrow keys, select it with “Enter” key. The “Home” key will bring you back to the main menu, “ESC” key back to the next higher menu level.

4.10.1 Menu „New measurement“

Brings you to the sub menu:



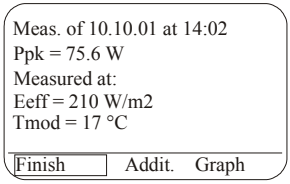
4.10.1.1 Menu “Single measurement”

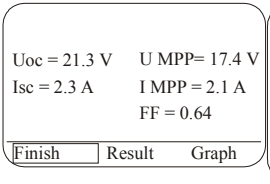
A single measurement is made and the results like Ppk and Rs will be calculated and displayed at once. The data is stored permanently and automatically. The i-v-curve can be displayed on the screen immediately.

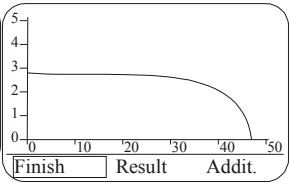
4.10.1.2 Menu “Rs measurement”

This method is adapted from a norm: two measurements at different irradiances, but same temperature and spectrum have

to be made. When the second measurement is finished the Rs will be calculated and displayed from the results of these two measurements. This method is much mure complicate than our standard method method to gain the Rs from only one i-v-curve.







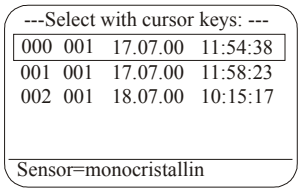
It is only implemented for completeness.

4.10.1.3 Obj. Index

The object index was implemented to allow marginal structuring of the measured data. Due to the lack of a alphanumerical keyboard no additional data can be added to the measurements. The object index no allows to assign a number to the measurements. So you can organize datasets that belong together (for example from one module) with the same object index. In the menu “Service” you can reset the object index to 1.

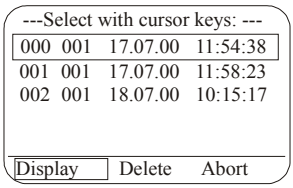
4.10.2 Menu „Stored meas.“

This function enables you to recall a former automatically stored measurement from internal storage (as long as you not already deleted the dataset). The datasets are displayed in a list identified by the date and time of the measurement. Locate a dataset with the arrow keys, select the dataset with “Enter”. if more than one page of datasets can be displayed you can select other pages with the keys “Left” and “Right”.



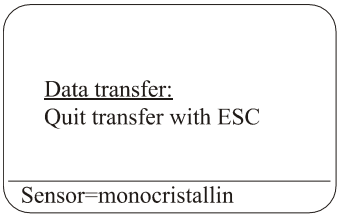
Now a menu with “Display”, “Delete” and “Abort appears. “Display” will again show the results of this measurement on the

display, “Delete” will delete the dataset from internal storage (caution: you can not undo this!), “Abort” brings you back to the main menu.



4.10.3 Menu „Transfer“

This function allows the control of the PVPM1000C through a connected external PC (see also chapter 8). Finish this function by pressing the ESC key.



4.10.4 Menu „Service“

Brings you to the following sub menu:

4.10.4.1 Menu “Select sensor”

You can select one of the sensors that are defined in the sensor database (see chapter 8.4.4).

4.10.4.2 Menu “Show version”

Shows the firmware version number.

4.10.4.3 Menu “Reset obj. index

Here you can reset the object index to a value of 1.

4.10.4.4 Menu Set Date/Time”

Here you can set date and time of the internal clock of the PVPM1000C, but it will be much more simple to do this with the program PVPM.disp (see chapter 8).

4.11 Messages

Message:	*Description:*
'Serial error'	An error in the serial connection between PVPM and PC ocurred
'No measured data'	Measured data is not yet available
'Configuration file not found!'	Internal error, consult manufacturer. PVPM cannot work without its configuration file
'Irradiance varies (ref-cell)!', 'Irradiance too low!', 'Irradiance varies (module)!'	The irradiance is not constant enough for the peak power measurement (for example due to moving clouds)
'not available'	This reusult cannot be calculated
'No room for new data!', 'Delete files from PVPM'	There is no space left on the internal permanent storage, you have to delete stored data from the permanent storage of the PVPM (see 4.10.1.3)
'Measurement runs', 'Please wait...'	Measurement is in process
'Error writing file '	An error ocurred storing the measured data
'Data transfer:', 'Quit transfer with ESC'	Data connection to PC invoked
'Measurement not yet possible'	The security delay between two measurements is not yet elapsed
'Calculation of Rs not possible'	Data is not sufficient for calculation of Rs. Redo the measurement

'Values not evaluablely'	Data is not sufficient for calculation. Redo the measurement
Voltage too high!	Immediately switch off the generator with the external security switch! The device could be damaged by the high voltage!
Service required!	The device is damaged internally and requires test and repair through authorised personell.
Wrong polarity!	The measuring cables are mounted in the wrong way! Switch off the generator with the external security switch immediately! The device will short circuit the generator if the polarity is wrong and can take harm. If you disconnect the cables under voltage a light arc can cause serious damage to health and material

5 External Security Switch 1000V / 20A

Use this switch to disconnect the peak power measuring instrument and I-V-curve tracer PVPM from the PV power before connecting or disconnecting the measuring cables to/from the PVPM. This avoids damages of your own health or the PVPM.

Usage:

Turn the knob at the switch in a neutral position "0" (both "0" positions are equal).

Put the measuring cable delivered with the PVPM as far as it will go to the sockets at the switch housing, red connectors to red sockets and black connectors to black sockets. You can reverse the two red connectors without harm, the two black ones also. Now connect the cables mounted at the switch to the PVPM (red to red, black to black).

Before you can make a measurement you have to turn the knob at the switch to one of the "1" positions.

Security hints:

CAUTION:
Do never forget to switch to "0" before handling the connectors at the PVPM!

If you detect a defect at the switch, the housing or the connection cables, the switch may under no condition be used any longer!

Only specially instructed professionals must do repairs!

Keep the switch and cables away from liquids, dust and dirt. Clean the surface with a wet cloth only.

6 Parameters affecting the Accuracy of the Measurement

Be sure, that there is no shadow (even not the smallest shadow!) affecting the module to be measured. Even the shadow of grass may cause an error! This is also true for the reference sensor.

The higher the irradiance to the module, the more exact will be the result. The irradiance measured by the combined sensor should be higher than 500 W/m2 if possible.

The combined Phox/Pt1000 sensor measures the cell temperature at the back of the reference cell. The PVPM expects this temperature to be nearly the same as that of the measured module. This will be true with sufficient precision if the reference cell and the PV module were exposed to the sunlight for same period of time (at least 5 minutes).

The alignment of the module re. the sun is not relevant. Very important is a sufficient irradiance to the module and precise alignment of the reference cell towards the module. Often the easiest way is to clip the combined sensor directly to the side or top of the measured module. However the sensor may also be installed in some distance to the module if you can grant the correct alignment.

Pay attention to the cooling openings of the reference sensor, these must not be closed or covered. This would cause an error in the temperature measurement of the reference cell and affect the quality peak power measurement.

Caution: even a few degrees deviation in the temperature of the reference cell towards the module temperature can cause a significant error in peak power measurement. Before a you make a measurement be sure, that the reference sensor and the module were exposed to the same ambient conditions for a sufficient period of time!

You can enhance the precision of the PVPM results by measuring the same object several times (e.g. 10) and after that do a statistical evaluation on these results.

Given below are once more the parameters, that are decisive for the accuracy of the measurements:

Accuracy of the peak power calculations from I-V characteristics on photovoltaic generators with the measuring device PVPM

Under following constraints the peak power designations of the PVPM have an accuracy of +/- 5% relating to the actual peak power value of the device under test:

- The device under test consists of mono- and polycristalline silicon cells
- The tested device is not (not even slightly) shadowed
- The irradiation reference sensor is not (not even slightly) shadowed
- The irradiation reference sensor must have largely the same spectral sensitivity as the tested device
- The measurement has to be carried out under natural sunlight
- The sun has to stand according to IEC60904 within +/- 10° at right angle to the active surface of the device under test
- The irradiation amounts according to IEC609004 at least to a total of 800W/m². On the basis of comparative measurements we find 600W/m² sufficing.
- The measurement of the irradiation has to take place instantaneously before or after the I-V characteristic, the time-lag between measurement of characteristic and irradiation has to be less than 10ms.

- The measured value of the irradiation reference sensor has to be adjusted with the measured temperature of the cell
- The measurement of the cell temperature has to take place instantaneously before/after the measurement of the characteristic within 1second and an accurateness of 1K
- The active surface of the device under test must lie in-plane with the irradiation reference sensor (within +/-5%)
- Before the measurement of the I-V characteristic the irradiation has to be constant enough for at least 10seconds (+/-10W/m²), that way misinterpretations of the temperature of tested device and reference sensor can be avoided
- The irradiation may not fluctuate around more than 10W/m² (PVPM will call attention in this case)
- Temperature of tested device and reference sensor has got to be balanced (no alteration of temperature my be indicated)
- Current and voltage of the device under test are measured with different measuring lines (four-wire measurement)

7 Installation of the Transfer Software PVPM.disp

PVPM.disp is delivered on a diskette or a CD-ROM. The medium contains a setup program for easy installation of the software on to your PC. The setup program will copy all necessary files to your hard disk and initializes the program. The installation can be performed by every person with basic experience of PC and MS Windows®.

For the installation the following steps are necessary:

1. Insert the program disk/CD containing the setup program (Disk 1) in to the corresponding drive.
2. Under “Start” select menu option “Execute”
3. In the now appearing edit line under “Open” you enter “x:setup” (were x is the drive letter of the installation media.
4. Press ENTER or the OK button. Now the setup program will be started and executed. Follow the messages on the screen.
5. Setup now copies all necessary files to your hard disk and will create a new program group for PVPM.disp..
6. After completing the installation please start PVPM.disp. The program should now work as described in the following text.

The operation of the program will be professed detailed in chapter 8 .

For the operation of the program these files are necessary:

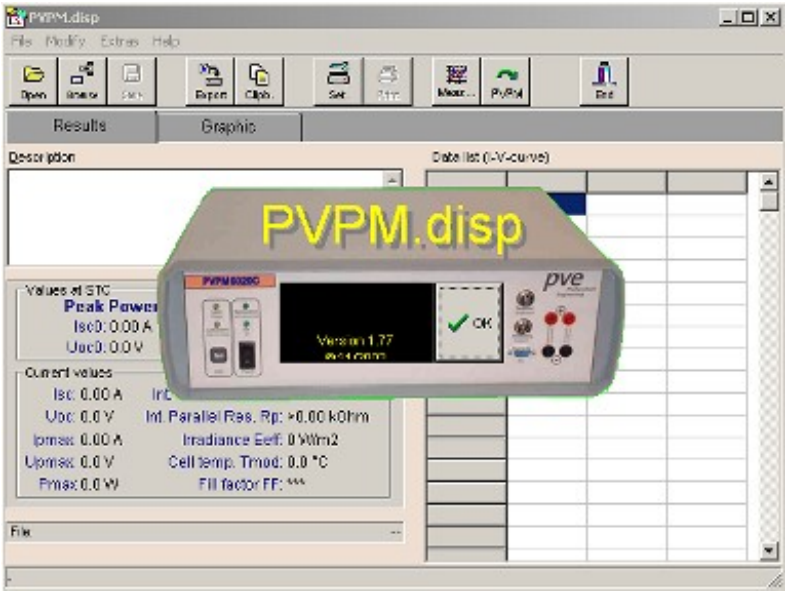
PVPMdisp.EXE	The main program
PVPMdisp.INI	Config file. You must not change this file manually!
PVPMdisp.HLP	Help file (not yet available)

The program will create files with the extension .SUI, which contains measured data from a I-V-measurement. When these

files were created automatically during a data transfer from PVPM1000C to PC the file name will contain the date and time of the measurement. A typical file name could be **24-05-01 14_17_04.SUI,** this file contains data from a measurement made Mai 24., 2001 at 2:17:04pm.

8 Operation of the Transfer Software PVPM.disp

For the installation of the software please refer to chapter7. After starting the software the following window appears:



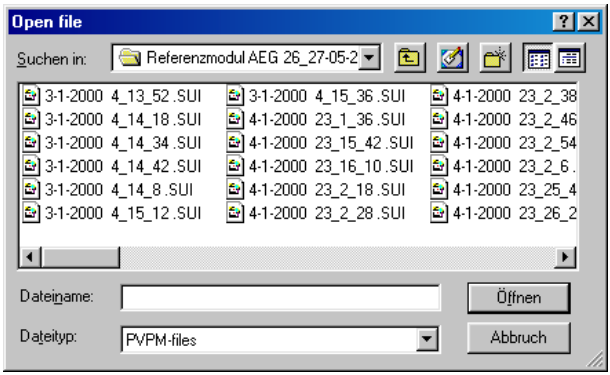
The displayed document is empty, all values are zero. Now you can make a measurement or get measurement data from the PVPM1000C. The new or received data will be stored to this document and you are able to continue evaluating these data or save it to a hard disk file. For the evaluation you can refer to the screen pages “Graphic” (line diagram of measured data) and “Results” display of results and list view of measured data). The function “Export” lets you export the data to different file formats for further evaluation in other software.

Buttons are grayed out, when they are not active. They change to normal state, when this function is meaningful.

8.1 Main Menu

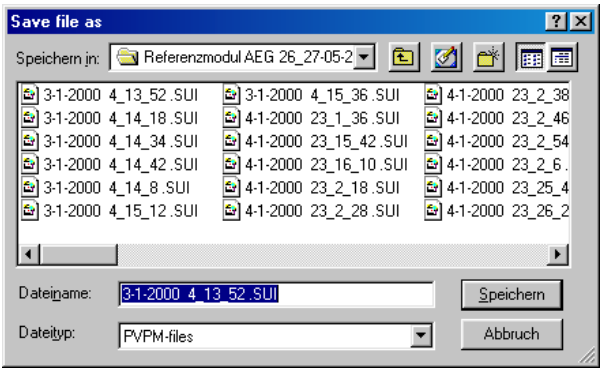
8.2 File

8.2.1 Open



I-V-curves saved to disk before can be reloaded using the „Open“ button. The loaded data will overwrite the data in memory. If you will use the existing data later you have to save it to disk file before loading other data. The files have the default extension .SUI.

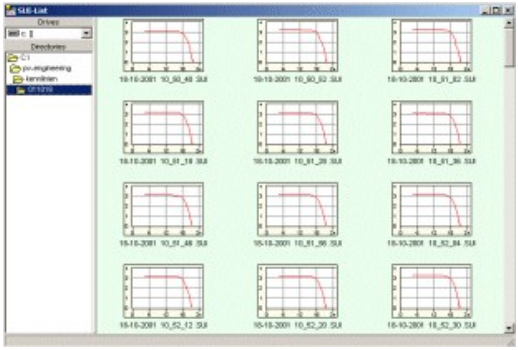
8.2.2 Save as...



Here you can save the current data to a disk file. Entries made in field “Remarks” will be save also. The program supports long file names. The default file extension is ".SUI".

8.2.3 Browse

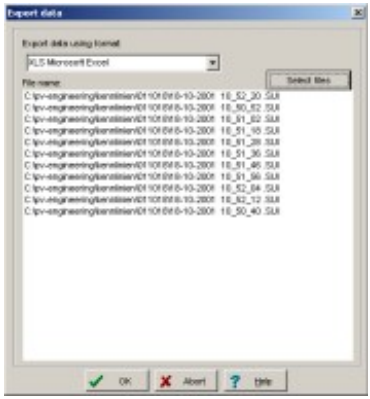
The browse window shows the thumbnail images of the measured curves in the selected directory. This gives you a quick overview over the existing measurements and you can detect a special curve.



If you go with the mouse cursor above one graphic a small hint window will display the significant values.

Doubleclicking the graph will open the file for evaluation.

8.2.4 Export

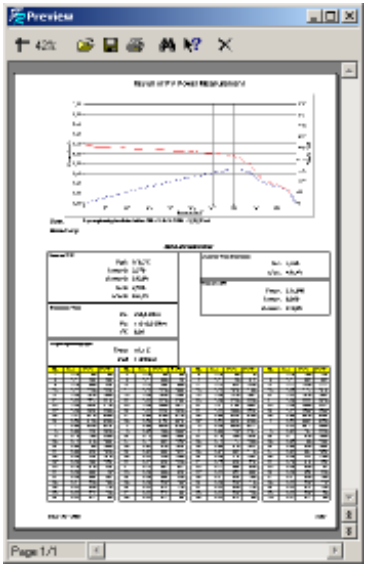


The current data can be exported to disk files with different file formats which can be read by other programs (e.g. spread sheet programs). You can use the format .DBF (dBase III+) and three different ASCII formats. For the selection of the right format please consult the manual of the destination program.

Please select the desired export file format from the combo box. Now enter a valid file name for the export file or select a existing one with the button “Search”, then press OK.

The export file will be written now and then you can open it with an other program.

8.2.5 Print



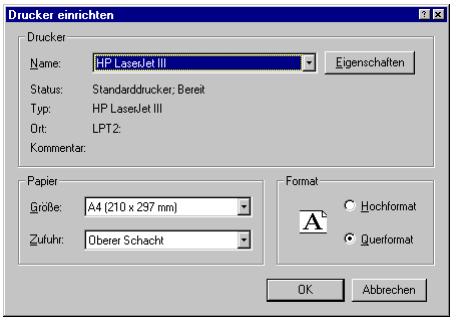
This button is context sensitive, that means that a graph will be printed when the graphic is currently displayed and a data list will be printed, when the results are displayed on screen.

Please pay attention to the fact, that in some cases the page orientation of the printer has to be changed before printing out. The print uses the whole available printing area.

The buttons on top of the preview window are from left to right:

Zoom factor
Save preview
Load preview
Print preview
Find text in preview
Help
Finish preview.

8.2.6 Printer Settings



Calls the windows standard dialogue “Printer Settings”. Select the desired printer settings here.

8.2.7 Quit Program

Here you finish the program PVPM.disp. The current data are not save automatically but you will get an warning, that you data should be saved before closing the program

> Don't forget:
> Finish "Transfer" on the PVPM1000C when you close PVPM.disp

Finish PVPM.disp always with the function "Quit program", the button "End" or the key combination <ALT>-<F4> and go back to System. It is also important, that you down your system properly afterwards, because else a data loss might occur due to a write back cache etc.

8.3 Edit

This function is only active when the cursor is placed in a text edit field.

8.3.1 Cut

Cuts the marked text and moves it to the clipboard.

8.3.2 Copy

Copies the marked text and moves it to the clipboard.

8.3.3 Insert

Inserts the contents of the clipboard at the cursor position.

8.4 Options

Before you use the following function "Measurement" please power on the PVPM1000C and select the menu option

"Transfer". The solar generator to be measured and the sensors should be mounted already.

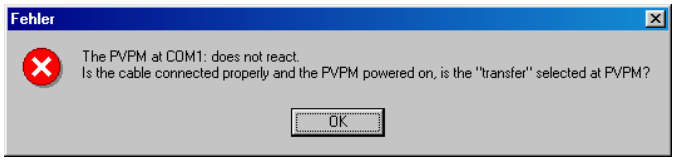
8.4.1 Start Measurement on PVPM / Button „Measure"

After starting the function the status line will display the message "Measurement processing– Please wait".

The measurement will take up to 2 seconds. Directly after the measurement the measured values will be transferred (process will be displayed in the status line) and the main window will display the values and results. Now you can display the data in a graph (chap. 8.5) or a list (chap. 8.6), export (chap. 8.2.3) or save to file (chap. 8.2.2).

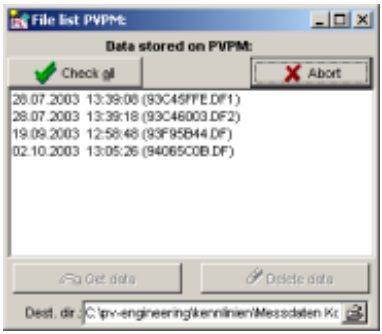
Important: When the measurement is initialized from the PC the data will **not** automatically be stored in the PCPM1000C!

If this message (see right) appears, the cable to PVPM1000C is not mounted properly or the function "Transfer" on the PVPM1000C is not activated.


Fehler
The PVPM at COM1: does not react.
Is the cable connected properly and the PVPM powered on, is the "transfer" selected at PVPM?
OK

8.4.2 Manage Files on the PVPM1000C

Here the measurement data stored on PVPM1000C will be displayed in a list (the PVPM1000C must be connected and online for this function). Now you can select data sets from the list (even more than one) and either transfer it to the PC for further processing (Button "Get data") or just delete it from the PVPM1000C (Button "Delete data").



Caution: Carrying out this function can not be cancelled!!

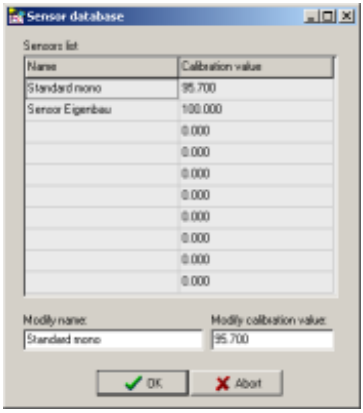
When you select data transfer the data sets will be transferred one after the other and the files are stored to disk automatically using a file name that contains the date and time of the measurement.

8.4.3 Synchronize PVPM to PC date/time

With this function the internal real time clock of the PVPM1000C is set to the PCs date/time.

8.4.4 Modify PVPM sensor database

You can connect different irradiance sensors to the PVPM. Every sensor has its own calibration value, so PVPM needs to know this value for correct operation. To make this simple during measurement you can define a table with up to ten different sensors, its names and calibration values, which will be stored in the PVPMs permant memory. So later on you just have to select the appropriate sensor. The name you give the sensor is more or less free. It will be displayed later on on PVPMs display and informs you about the actually selected sensor. You can select the sensor at the PVPM via the menu “Service” and “Select sensor”.



If you want to use this function the PVPM must be connected and ready for data transfer! When you start this function the database is loaded from PVPM and will be stored back to PVPM when you close this form.

To enter a new value just select a free line and enter the values in the edit fields below the table.

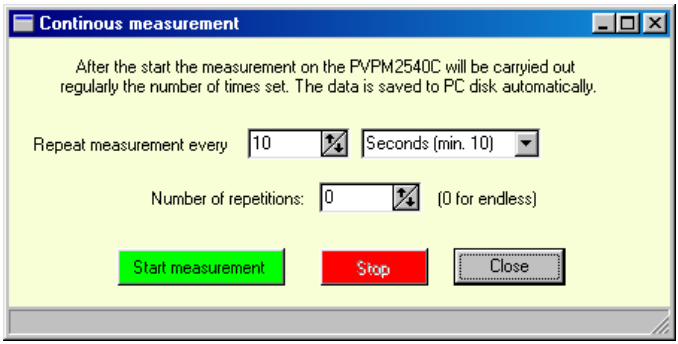
After finishing all entries press OK. Now you will be asked whether the data should be transferred to PVPM. Normally you should select “Yes” here.

8.4.5 Calculate internal series resistor

Basing on the values of short circuit current, open circuit voltage, and the i and v value of the MPP the PVPM can calculate the effective solar cell curve and with this the expected internal series resistor R_s. This theoretical value can be compared to the actually measured value and give a hint, whether there are problems for example in the cabling.

8.4.6 Continous measurement

This function allows the automatically time measurement driven from PC.


Continous measurement
After the start the measurement on the PVPM2540C will be carryied out regularly the number of times set. The data is saved to PC disk automatically.
Repeat measurement every
10
Seconds (min. 10)
Number of repetitions:
0
(0 for endless)
Start measurement
Stop
Close

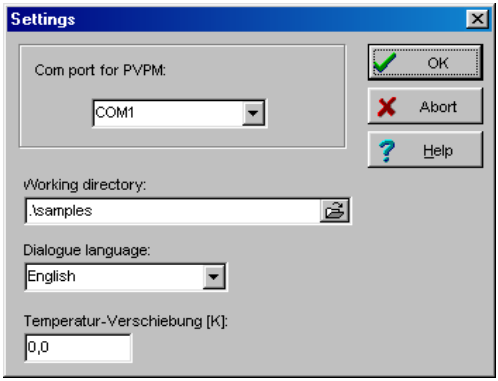
Set the desired time interval and the time unit (seconds, minutes, hours) for the execution of the measurement and the number of repetitions (0, if measurements shell be repeated infinite).

After pushing the button “Start measurement” the measurement runs automatically and can be cancelled by the “Stop” button. The measured data will automatically stored to files in the predefined directory (see below). The file names contain the date and time of the measurement.

The automatic measurement will stop, when the given number of repetitions are finished or when the PVPM does not answer.

8.4.7 Settings

All changes made here will be saved automatically and are valid until the next change.



8.4.7.1 Select Serial Port

You can select the serial port (COMn:) used for PVPM communications from the combo box.

8.4.7.2 Working directory

The working directory is used in file open and file save dialogs and for the automatically saving of files. Select here the directory which contains your measured data or which the measured data should be saved to. The entry field has a button at its right side. Press this button to display a directory selection dialog.

8.4.7.3 Dialog language

PVPM.disp supports the dialog languages English and German. The language can be changed during program execution. Just select your desired language from the combobox “dialog language”. After you close the dialog box the labels of PVPM.disp will be displayed in the selected language. PVPM.disp will remember language setting at the next start.

Please note, that the standard and system dialogs will always be displayed in the language of the current windows version!

8.4.7.4 Temperature correction

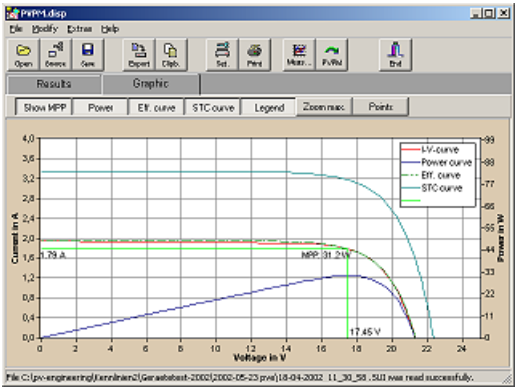
Sometimes it may be useful to add a correction factor to the measured temperature values. In this case you can enter the factor here. The factor will be added to the measured temperatures: enter a negative value, if you want to decrease the temperature. If the factor is not zero the displayed temperatures will be displayed like “xx.x°C korr.” to remember you, that this value is not the measured one.

8.4.8 Firmware-Update

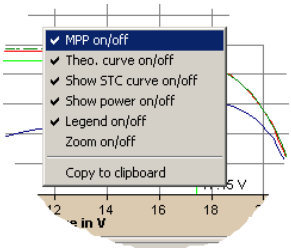
This function is for service purposes only and not documented here.

8.5 Graphics

After loading the data of a measurement you can display the graph by selecting the tab “Graphics” (if not already displayed).



In the graphical display you can draw up a rectangle with the mouse cursor (from top left to bottom right with pressed left mouse button). This marked region then will be displayed zoomed. To come back to normal view just click onto the drawing region. If you press the Shift-Key and the right mouse button in the viewing area and keep the buttons pressed, you can move the graphic area in every direction (pan).



Clicking the viewing area with the right mouse button lets a popup menu appear. The same functions are available if you use the button bar on top of the graphics region. The following options are available:

8.5.1.1 MPP display on/off (button “Show MPP”)

You can select whether the MPP shell be displayed in the diagram or not. Note: The displayed MPP is not exactly one of the measured data points but will be interpolated.

8.5.1.2 Theo. curve on/off (button “Eff. curve”)

You can select whether a curve approximation will be performed on the data and whether this curve will be displayed additionally to the measured curve. Depending on the measured data the calculations may be not possible.

8.5.1.3 Show STC curve on/off (button “STC curve”)

If a curve can be calculated up to STC conditions it also can be displayed. Here you can switch the display of this curve on or off. The axis scale will be corrected automatically (if necessary).

8.5.1.4 Show power on/off (button “

You can select whether the power graph is displayed or not.

8.5.1.5 Zoom on/off (button “Zoom max”)

The scale for the y-axis is changed to expand the curve to the maximum display.

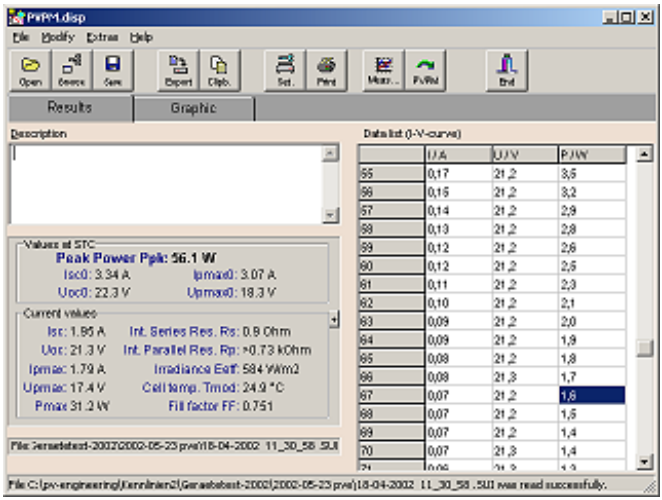
8.5.1.6 Legend on/off (button “Legend”)

A legend of the displayed graphs can be displayed optionally. Here you can switch the display of the legend on or off.

8.5.1.7 Copy to clipboard (button “Clipb”)

Copies the actual graphic to the clipboard, you can enter this copy for example into a word document.

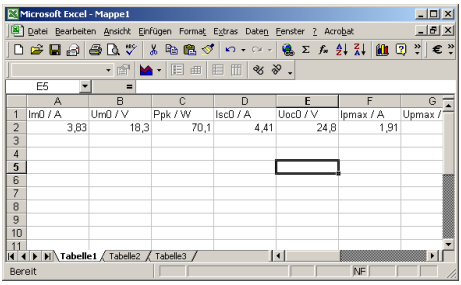
8.6 Results / Lists



By clicking the tab “Results” the page with results will be displayed. It is not possible yet to edit this data here. However the list with results and measured data can be printed (see 8.2.5)

With the button “Clipb” you can copy important data in a tabular form to the clibboard and then for example into MS Excel.

So you can easily setup a table of different measurements and compare them using a software other then PVPM.disp without exporting the files.


Microsoft Excel - Mappe1
Datei Bearbeiten Ansicht Einfügen Format Extras Daten Fenster ? Acrobat
E5
A B C D E F G
Im0 / A Um0 / V Ppk / W Isc0 / A Uoc0 / V Ipmax / A Upmax /
3,83 18,3 70,1 4,41 24,8 1,91
Tabelle1 Tabelle2 Tabelle3
Bereit
NF

8.7 Help (not yet implemented)

8.7.1 Contents

Displays the contents of the online help.

8.7.2 Search

Here you can search within the online help.

8.7.3 Use help

Basic hints for the windows help system.

8.7.4 Info

Displays an information window with the version number of the program.

9 Hardware Information

(Changes reserved)

Build in a stable metal case with carrying handle and tough front panel.

9.1 Measuring Unit:

Sampling rate max. 100kHz, resolution 12Bit,
Accuracy of the a/d converter better 1%
Peak power measurement: ±5%
Reproducement: ±2%
Duration of single measurement: about 2 seconds
Phox sensor with integrated Pt1000 sensor measures irradiance and cell temperature. Other commercially available sensors as e.g. ISET-Sensor® can be connected using a reliable cable connection.
Pinout of sensor plugs:
Irradiance:
3 pin female chassis socket Typ Lumberg KFV30 (plug: SV30)
Pin 1 = U+
Pin 2 = not used
Pin 3 = U-
Temperatur2:
4 pin female chassis socket Lumberg KFV40 (plug: SV40)
Pin 1 = +Current source (~1 mA)
Pin 2 = +Pt1000
Pin 3 = -Pt1000
Pin 4 = -Current source (~1 mA)

Measuring ranges of the PVPM:

Standard Meas.Range	Voltage [V]	Current [A]	Tempe-rature	Irradiance
PVPM2540C	25/50/100/250	5/10/20/40	-100°C - +120°C	0 - 1300 W/m2
PVPM6020C	25/100/300/600	2/5/10/20		
PVPM1000C	25/100/500/1000	2/5/10/20		
PVPM1000C40	25/100/500/1000	2/5/10/40		

Peak power: up to 40kW

Ranges for current and voltage can be combined in any order
An optimal range is selected by the device automatically.

9.2 Calculation Unit:

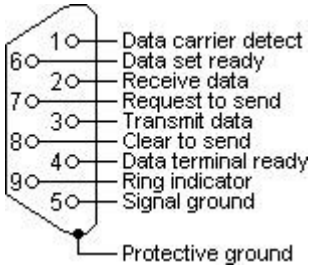
Processor 386sx-compatibel, 33MHz, memory 2MByte
Flash disk 0.9MB (can store more than 100 results)
Watchdog, real time clock
No mechanically moved parts like hard disk, fan etc.

9.3 Display:

LCD display with CCFL lighting, resolution 256 x 128 pixels, monochrome, high contrast through white on black display

9.4 Operation:

Menu driven with few keys mounted to the front panel
Operation and evaluation alternatively by Windows software, connected via RS232 (19200Bd)



9.5 Power Supply:

Lead-acid-accumulator 12V/2.2Ah or 12V/7.2Ah,
Internal power supply 230V/50Hz, power consumption 40W,
fuse 5x20, 250V 0.25A Slow at der backside of housing
Integrated battery charger with overload protection for accu
Display of battery state with LEDs at the front panel

9.6 Dimensions

Width: 48cm, height: 16cm, depth: 34cm (2540C, 6020C) / 39cm

9.7 Operation Conditions:

	Temperature:	Humidity
Operation:	0°C to 40°C	10% to 90% (not condensing)
Storage:	-10°C to 85°C	5% to 95%

10 List of symbols

AM	Air-Mass, relative way length for the sunlight through the atmosphere of the earth
cT	Temperature coefficient of the maximum power
E	Irradiance
E0	1000 W/m2 (Irradiance at STC)
Eeff	Irradiation, measured with a cristalline pv cell
EN	800 W/m2 (Irradiance for NOCT)
FF	Fill factor
I	Current
I0	Sperrstrom
Im	Short form for Ipmax
Iph	Photo current
Ipmax	Current at Pmax
Ipmax0	Current at Pmax (at STC)
Isc	Short circuit current
Isc0	Short circuit current (at STC)
m	Normalized slope of the solar characteristic curve
M	Slope of the characteristic curve at I=0
MPP	Maximum Power Point, other description for Pmax
NOCT	Nominal Operating Cell Temperature, cell operating temperature at TambN and EN.
P	Power
Pmax	Actual maximum power of a solar cell
Ppk	Peak-Power, maximum power of the solar cell at STC
R	Resistance
Rp	Parallel resistance
Rpv	Photovoltaic resistance (calculation factor only, no real resistor)
Rs	Serial resistance
STC	Standard Test Conditions for the determination of Ppk
t	Time
Tamb	ambient temperature
TambN	20°C (ambient temperature for NOCT)
Tj0	25°C (cell temperature at STC)
Tmod	actual Module temperature (at the backside of the module)
U	Voltage
Um	Short form for Upmax
Uoc	Open circuit voltage
Uoc0	Open circuit voltage (at STC)
Upmax	Maximum power voltage

11 Reasons for decreased Power and Yield of PV Generators

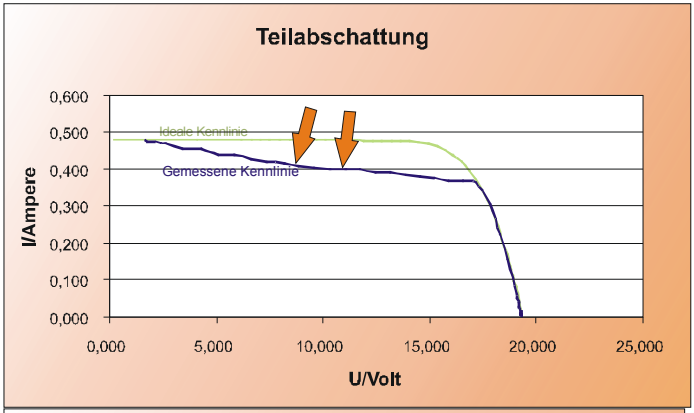
Error	To be detected by:	Possible reason / ***workaround***
System configuration chosen inadequately	Measurement of mismatch losses	Design fault / *redesign*
Erroneous match of strings and inverter	Fed power too low for location and in relation to nominal generator power	Design fault / r*edesign, replacement of inverters*
Cast shadow	I-V-curve shows "bulge", **peak power** too low, optical check	Barrier near module (e.g. tree, chimney, birds excrements) / *remove barrier*
Diffuse shading (may be hardly visible for bare eye!)	I-V-curve is "impressed", **peak power** too low	Barrier in some distance to module (high portion of diffuse light) / *remove barrier*
Corrosion at plugs and cables	**Serial internal resistance Rs** too high	Material, planning or mounting fault / Clean*, replacement*
Delamination of cell embedding	see **shading diffuse**	Material / production fault / *Replacement*
Bubbling in resin	see **shading diffuse**	Material defect / *replacement by supplier*
Transparent covering material (glass, plastics, resin) becomes blind	Optical check, **peak power** too low (s. a. **shading diffuse**)	Material defect / *replacement by supplier*
Discolouring of the transparent cover material (plastics, resin)	Optical check, **peak power** too low (s. a. **shading diffuse**)	Material defect / *replacement by supplier*
Intrusion of water into the laminate, leads to other problems (corrosion, discolouring)	Optical check	Material or production fault / *replacement by supplier*
Faults in the crystalline structure of single cells (hot-spot effect)	see **shading diffuse**	Production fault / *reduction of price, replacement by supplier*
Pollution of the module by dust	Optical check, see **shading diffuse**	High dust impact. Check modules periodically / *cleaning*
Moss / algae on module, birds excrements	see **cast shadow**	Normal for several regions / *cleaning*
Broken cover glass, leads to	Optical check	Hailstorm, mounting or

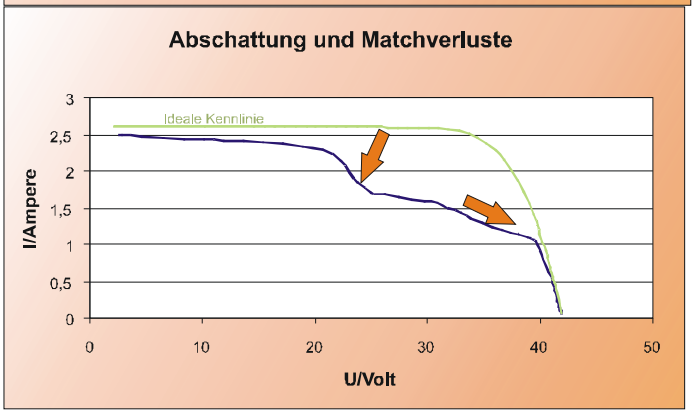
other problems (corrosion, discolouring)		transportation fault / *replacement by supplier*
Break of single cells in module	**Peak power** too low, possibly deformation of I-V-curve	material defective / *replacement by supplier*
Improper electrical connections in module	**Peak power** too low, **internal series resistance Rs** higher than calculated	Fault in soldering, material defective, corrosion / *replacement by supplier*
Bypass diode defective (short circuit)	**Peak power of** strings reduced by module power	Overload, material defective / *repair*
Bypass diode mounted the wrong way	**Peak power** of strings reduced by module power	Mounting fault / *repair*
No bypass diode mounted or diode defective (high resistance)	Shading of one module reduces power of the string dramatically	Planning / mounting fault / *repair*
Dimension of cabling too small	**Internal series resistance Rs** too high	Design fault / *replacement of cables*
Cable defective (e.g. break, corrosion)	**Internal series resistance Rs** too high	Mounting fault / *repair*
Insufficient mounting of connectors	**Internal series resistance Rs** too high	Mounting fault / *repair*
Corrosion in screwed or plugged connectors	**Internal series resistance Rs** too high	Mounting fault / *cleaning, repair*
Insufficient preselection of modules regarding peak power	**Peak power** of plant too low	Planning or mounting fault (match losses) / *New preselection of the modules after peak power measurement*
Insufficient preselection of single cells regarding power during module production	**Peak power** of module too low	Production fault / *reduction of price, replacement by supplier*
Short circuit between cells in the module	**Peak power** of plant too low, open circuit voltage U_{oc} too low, shape of curve	Production fault / *replacement by supplier*
Fabrication tolerances in cell production	**Peak power** too low, shape of curve	Production fault / reduction of price, *replacement by supplier*

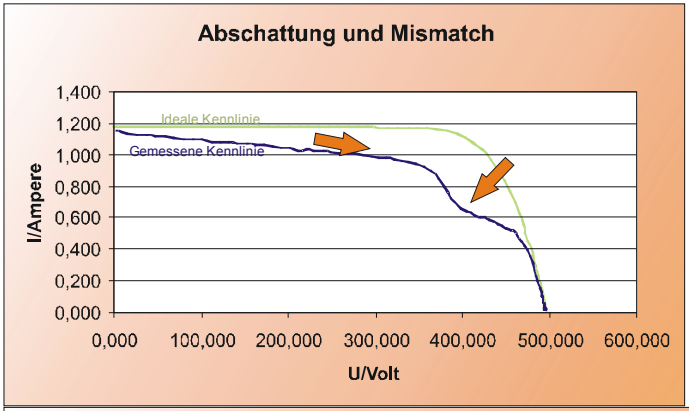
Please notice: some faults may appear only under special operating states, e.g. high module temperatures.

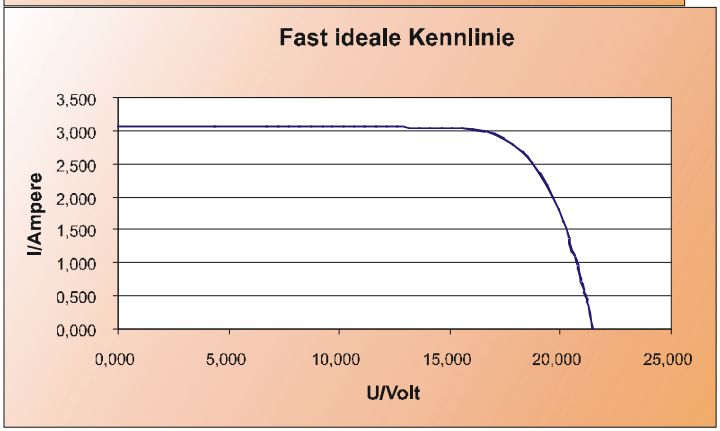
This compilation does not claim to be complete or free of failures.

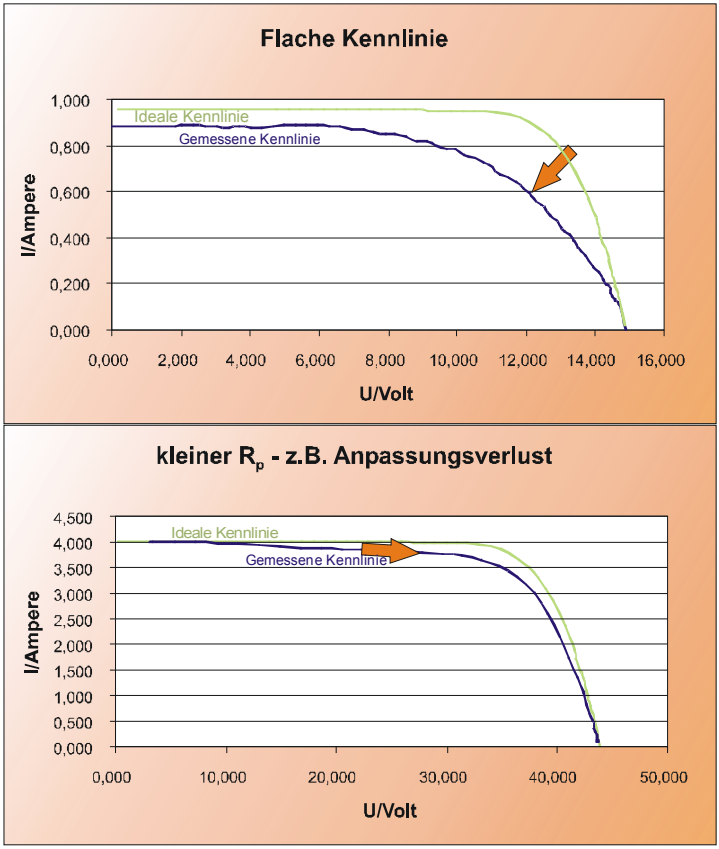
12 Sample Curves






Abschattung und Mismatch
Ideale Kennlinie
Gemessene Kennlinie
I/Ampere
1,400
1,200
1,000
0,800
0,600
0,400
0,200
0,000
0,000
100,000
200,000
300,000
400,000
500,000
600,000
U/Volt


Fast ideale Kennlinie
I/Ampere
3,500
3,000
2,500
2,000
1,500
1,000
0,500
0,000
0,000
5,000
10,000
15,000
20,000
25,000
U/Volt


Flache Kennlinie
Ideale Kennlinie
Gemessene Kennlinie
I/Ampere
1,000
0,800
0,600
0,400
0,200
0,000
0,000
2,000
4,000
6,000
8,000
10,000
12,000
14,000
16,000
U/Volt
kleiner Rp - z.B. Anpassungsverlust
Ideale Kennlinie
Gemessene Kennlinie
I/Ampere
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
0,500
0,000
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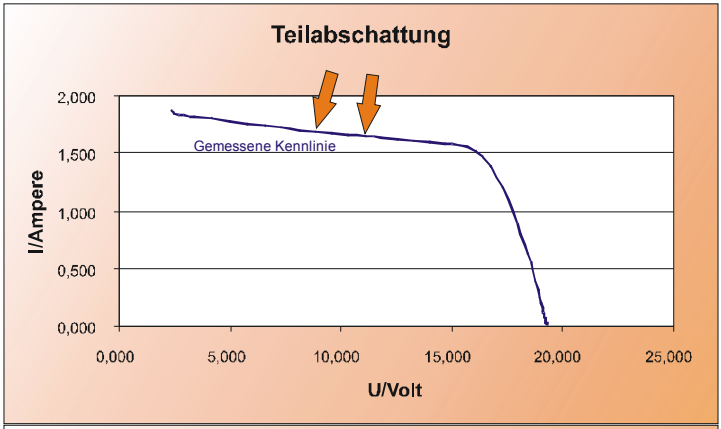
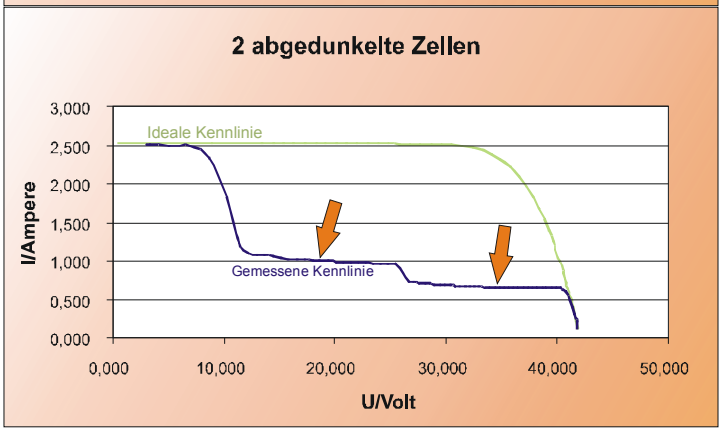
40,000
50,000
U/Volt


Teilabschattung
I/Ampere
2,000
1,500
1,000
0,500
0,000
Gemessene Kennlinie
0,000
5,000
10,000
15,000
20,000
25,000
U/Volt


2 abgedunkelte Zellen
I/Ampere
3,000
2,500
2,000
1,500
1,000
0,500
0,000
Ideale Kennlinie
Gemessene Kennlinie
0,000
10,000
20,000
30,000
40,000
50,000
U/Volt

13 Glossary

13.1 Azimuth (ß) and elevation (α)

For the effective use of solar radiation the modules and collectors are arranged in a way that makes a preferably large solar crop possible. In this connection the wave angle of the sun, but also the 'azimuth' and the elevation of the modules and collectors play a certain part. The azimuth angle specifys with how many degrees the surface of the modules or the collectors diverge from the exact adjustment to the south. The elevation pertains the deviation from the horizontal. Studies substantiate that solar plants with an azimuth of 0° and an elevation of about 30° are aligned in the best possible way. Nevertheless small deviations are not implicitly problematic: with the orientation to south-east or south-west still around 95% of the possible crop can be realised. Larger plants are, to enhance the profit, reorientated towards the sun by electric motors. (see as well tracking).

For measurements with the PVPM the accurate arrangement of the insolation sensor with the modules is very important. The sensor has to 'see the same sky' as the modules. At the same time it is to be taken in account that by reflections from the environment (by house walls or other light surfaces) the incidence of light on the modules and the sensor can be intensely influenced.

13.2 Slope of the roof

When planning a solar plant the question for the slope of the roof (e.g. on the internet) leads to wrong conclusions, as it is not the slope of the roof, but the slope of the collectors. Through an appropriate elevation and attachment the collectors can be brought into a good position even if the slope or the adjustment of the roof are disadvantageous.

For the optimum use of solar radiation the sun rays should fall on the collectors in a right angle. The optimum elevation and angle of setting-up correspond to the geographical latitude of a location. (Freiburg is located on the 48. degree of latitude; Lübeck on the 54. degree of latitude) Since the sun stands higher in the summer than in the winter it depends on in which time of the year the solar equipment is predominantly being used. Photovoltaic plants for example carry the highest yield on long summer days, while thermal solar plants are taken to support heating installations in the winter. As a rule of thumb for the angle of setting up a latitude of -10° in the summer and a latitude of +10° in the winter is considered to be effective.

Not to be confused with the slope is the orientation (azimuth) to the south. In practice smaller deviations from the optimum slope or orientation decrease the productivity insignificantly. A temporary clouding of the collectors impairs the effectiveness far more.

13.3 DC

Short for direct current, as it is being produced by solar cells and modules and stored by the battery. If many solar cells are connected in series to a module, the voltages mount up.

13.4 Degradation characteristic

The degree of efficiency of amorphous solar cells declines at the beginning of the phase of irradiation rapidly and first stabilises after 3 weeks to 5 month. Next to this irreversible degradation, another reversible degradation is taking place. That means amorphous solar cells have a better degree of efficiency in spring-/summer-time compared to autumn/winter.

13.5 Direct radiation/ diffuse radiation

Direct radiation (casting shadows) meets a surface without scattering through components of the earth' atmosphere. Through scattering (fog, haze, clouds) diffuse/ indirect radiation develops.

13.6 Generator

Lat.:producer. Generators dissipate other forms of energy into current. In solar techniques only the entirety of the interconnected photovoltaic modules is characterised as generator or as solar power plant.

13.7 Global/total radiation

Denotes the irradiation on the earth by the sun that hits a horizontal surface. It is composed of the direct irradiation and the reflected irradiation (e.g.: by snowfields).

13.8 Short-circuit current and solar cells

Current that circulates, if the positive and the negative pole of the cell get connected, that means when there is no resistor or load between the two poles. It is not dangerous for the cell, but a disconnection might cause a light arc which is dangerous for health and environment!

13.9 Mismatching

The connection of weak and better modules in a string, whereby the weaker module in a row affects the current and that way impairs the total power.

13.10 MPP

Denotes the point of maximum power. A solar cell has in connection of every magnitude of irradiation to a certain magnitude of temperature and light spectrum a point of maximum power on its I-V-characteristic. The product of usable current and corresponding current of a solar cell does not always have the same value.

13.11 Tracking

The module-surfaces of 'trackers' follow the state of the sun during the course of the day. The tracking can be carried out by one or two axis, whereby the production of two-axle tracking is more effective. Compared to a permanent south orientated plant the annual yield increases with approximately 30%. Tower mounted, tracked and elevated solar plants allows the choice of an optimum position. That way, irrespective of structural circumstances, a panning range free from shadows is made possible.

13.12 Peak Power

To guarantee the comparability of power output of PV-moules it was generally accepted that the nominal power of a module is measured with the boundary conditions temperature of cell 25°, irradiation 1000W/m² and a spectrum of light according AM=1,5, and named “Peak Power” (some producers also characterise it as “nominal value”). The boundary conditions are called Standard Test Conditions (STC).

Unfortunately the natural appearance of the STC is very seldom, that is why the relevant measurements so far were only realised in laboratories, where the conditions had to be produced under high effort.

With the new method of the Peak Power -and characteristic line-measuring device, a spate of PVPM, it is now possible to realise

these measurements under actual environmental conditions - the measuring device converts them into STC. Thus after just one characteristic line measurement the Peak Power Ppk, the internal series resistance Rs and the parallel resistance Rp are available as output. This output is, in comparison with the specified value, an indication for different errors in the PV-Generator, that way they simplify efficiency control and error search.

13.13 Performance Ratio

The “Performance Ratio” means in, photovoltaic, the ratio of available profit and specified value of a plant. The Performance Ratio is the quotient of the yield of alternating current and nominal yield of generator DC. It indicates what proportion of the current produced by the generator is in real terms available. PV-plants of high capacity reach a Performance Ratio of more than 70%. The Performance Ratio is often denominated as quality factor (Q). Solar modules on the basis of crystalline cells reach a quality factor of 0,85 to 0,95, network coupled plants average out at 70% to 75%.

13.14 Phox-sensor

The principle of the Phox (**PHO**tovoltaic Lu**X**) -sensor is that the current from the photovoltaic cell, which is almost linear to the irradiation of the cell, is conducted through a so called shunt, a particular resistor. The voltage which falls on part of the resistor is on its turn linearly dependant from the irradiation and can be easily measured with the measuring device. Disadvantage: every sensor has got to be calibrated separately: the calibration value is the voltage delivered by the sensor, when it is exposed to the Standard-Test-Conditions (STC).

13.15 Internal series resistance

This resistance results physically from the material being used for the production of the module as well as from its cable connection-it has usually a constant value. It amounts in crystalline modules around 1ohm, in thin-film module more than 2 ohm.

The measurement of the internal series resistance is latterly possible with the measuring device of the PVPM series. For that purpose just one I-V-curve of the module has to be measured. With this curve the device calculates the Rs, as well as the Ppk and the parallel resistance Rp automatically.

The theoretically value to be due of the internal series resistance Rs can be calculated. The calculation can be carried out with the software PVPM:disp, if the STC-characteristics Uoc, Isc, UMpp and IMpp of the module are known.

The calculates Rs can be compared to the measured value which the PVPM-measuring device hands out after the characteristic curve measurement. If the measured value is too high the wiring has to be checked for burst, corrosion, connection errors or wrong dimensions.

13.16 Solar Constant

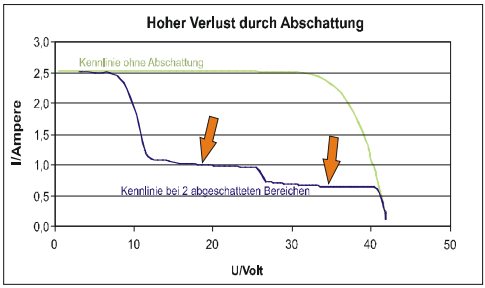
Denotes the solar radiation that hits vertically on a surface outside the atmosphere. s=1,37 kW/m². Outer space the solar radiation is almost constant; on earth it fluctuates in the course of daytime or time of the year and varies depending on latitude and weather. The maximum value on earth lies between 0,8 and 1,0 kW/m². In annual means the irradiation in Germany amounts according to region between 950 and 1100 kWh/m².

13.17 Solar irradiation / insolation

The solar irradiation is put together by the radiation which is directly from the sun and divers indirect proportions. Those are the by the environment reflected radiation, e.g. snowfields reflect especially intensive, the radiation of the blue sky and other diffuse radiation. For the exact calculation of the energy that hits a surface the angle between sunrays and surface is decisive. It changes according to time if year and time of the day. Informations about the exact calculation offers the below-mentioned internet address. The radiation is delimited by several factors; even if the sky is beaming blue only around 90% of the total solar energy arrives on earth.

13.18 Current-Voltage-Characteristic

The Current-Voltage-Characteristic of a PV-Generator shows different qualities and problems of the generator and is the basis of a few substantial specific values.



For example partially or hard shading will modify the characteristic as well as high internal series resistance and defective or missing bypass diodes.

Besides short circuit current Isc and open circuit voltage Voc, voltage and current at the maximum power point (MPP) Ipmax and Vpmax as a result you get the fill factor FF:
FF = Isc*Voc/(Ipmax*Vpmax)

The i-v-curve is the basis for the calculation of the effective solar curve, which then allows the determination of the peak power Ppk and the internal series resistance Rs.

14 Appendix A

14.1 Display lamps in the panel:

Mark	Function
Charge	Lights up, when accu is charged
State of Charge	Lights up red, when accu is discharged (charge necessary at once) Lights up green, when accu is ready Lights up yellow, when accu charge is finished
Grid connection	Lights up, when grid is connected and switched on
On	Lights up, when device is powered on (readiness is displayed on LCD screen)

14.2 Speaker signals:

PVPM1000C reports messages and operation state by speaker signals: in the following deep sounds are represented by „da“, higher sounds by „dee“.

Sound	*Meaning*	*Reaction*
Click	„key click“ is simulated while you press a key	--
dee	During operation: signals start or end of an function	--
da	Error (common)	Pay attention to further statements about the kind of error
de	If this signal comes with the first appearance of the main menu, the device is ready	Device is ready
da or da-da	Directly after switching power on: processor is o.k.	--
da or da-da followed by da-da	Directly after switching power on: the lithium battery of the processor is empty.	Service required
dee-dee-da-da	LCD display does not react	Switch the device off and after a little while on. If the error appears again, service is necessary
dee dee	After file transfer to PVPM (service only)	File transfer to PVPM o.k.
da-dee-da	After file transfer to PVPM (service only)	File transfer to PVPM not o.k., rest of destination file will be deleted
dee-dee-dee-dee	During measurement. irradiation is too low or varies	Measurement is incorrect an will be dropped
dee-dee-dee-da-da-da-dee-dee-dee	A/D converter could not be initialized	Service required

15 *EC Declarations of Conformity*

EG-Konformitätserklärung im Sinne der EG-Richtlinien
EC Declaration of Conformity *as defined by the EC Directives*

- EMV/*EMC* 89/336/EWG, geändert durch/changed by 93/31/EWG
- Niederspannung/*Low Voltage* 73/23/EWG

Der Hersteller / *The manufacturer*

PV Engineering GmbH
Reinickendorfer Str. 2
58642 Iserlohn, Deutschland/*Germany*

erklärt hiermit, dass folgende Produkte / *certifies that the products*

Produkt: *Product:*	I-U-Kennlinienmessgerät *I-V-Curve tracer*
Typ: *Type*:	PVPM2540C
Seriennummer: *Serial No*.:	PVPM2540C00403
Baujahr: *Year of manufact*.:	2003

den Bestimmungen der (den) oben bezeichneten Richtlinien entspricht.
are in conformity with the directive(s) mentioned above.

Folgende harmonisierte Normen wurden angewandt:
The following standards are in use:

DIN EN 55022
DIN EN 61000-6-1: 2002-08
DIN EN 61000-6-2: 2002-08
DIN EN 61000-6-3: 2002-08
DIN EN 61000-6-4: 2002-08

Iserlohn, 01.05.2003
(Ort, Datum)

Dipl.-Ing. Klaus M. Schulte
Geschäftsführer/Managing Director

EG-Konformitätserklärung im Sinne der EG-Richtlinien

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- Niederspannung/*Low Voltage* 73/23/EWG

Der Hersteller / *The manufacturer*

PV Engineering GmbH
Reinickendorfer Str. 2
58642 Iserlohn, Deutschland/*Germany*

erklärt hiermit, dass folgende Produkte / *certifies that the products*

Produkt: *Product:*	I-U-Kennlinienmessgerät *I-V-Curve tracer*
Typ: *Type*:	PVPM6020C
Seriennummer: *Serial No*.:	PVPM6020C00103
Baujahr: *Year of manufact*.:	2003

den Bestimmungen der (den) oben bezeichneten Richtlinien entspricht.
are in conformity with the directive(s) mentioned above.

Folgende harmonisierte Normen wurden angewandt:
The following standards are in use:

DIN EN 55022
DIN EN 61000-6-1: 2002-08
DIN EN 61000-6-2: 2002-08
DIN EN 61000-6-3: 2002-08
DIN EN 61000-6-4: 2002-08

Iserlohn, 01.03.2003
(Ort, Datum)

Dipl.-Ing. Klaus M. Schulte
Geschäftsführer/Managing Director

EG-Konformitätserklärung im Sinne der EG-Richtlinien

EC Declaration of Conformity *as defined by the EC Directives*

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- Niederspannung/*Low Voltage* 73/23/EWG

Der Hersteller / *The manufacturer*

PV Engineering GmbH
Reinickendorfer Str. 2
58642 Iserlohn, Deutschland*/Germany*

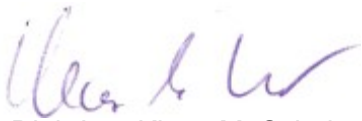
erklärt hiermit, dass folgende Produkte / *certifies that the products*

Produkt: *Product:*	I-U-Kennlinienmessgerät *I-V-Curve tracer*
Typ: *Type*:	PVPM1000C
Seriennummer: *Serial No*.:	PVPM1000C00103
Baujahr: *Year of manufact*.:	2003

den Bestimmungen der (den) oben bezeichneten Richtlinien entspricht.
are in conformity with the directive(s) mentioned above.

Folgende harmonisierte Normen wurden angewandt:
The following standards are in use:

DIN EN 55022
DIN EN 61000-6-1: 2002-08
DIN EN 61000-6-2: 2002-08
DIN EN 61000-6-3: 2002-08
DIN EN 61000-6-4: 2002-08



Iserlohn, 01.10.2003 Dipl.-Ing. Klaus M. Schulte
(Ort, Datum) Geschäftsführer/Managing Director

EG-Konformitätserklärung im Sinne der EG-Richtlinien

EC Declaration of Conformity *as defined by the EC Directives*

- EMV/*EMC* 89/336/EWG, geändert durch/changed by 93/31/EWG
- Niederspannung/*Low Voltage* 73/23/EWG

Der Hersteller / *The manufacturer*

PV Engineering GmbH
Reinickendorfer Str. 2
58642 Iserlohn, Deutschland*/Germany*

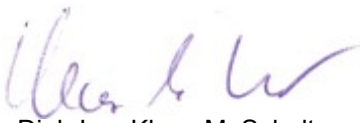
erklärt hiermit, dass folgende Produkte / *certifies that the products*

Produkt: *Product:*	I-U-Kennlinienmessgerät *I-V-Curve tracer*
Typ: *Type*:	PVPM1000C40
Seriennummer: *Serial No*.:	PVPM1040C03004
Baujahr: *Year of manufact*.:	2004

den Bestimmungen der (den) oben bezeichneten Richtlinien entspricht.
are in conformity with the directive(s) mentioned above.

Folgende harmonisierte Normen wurden angewandt:
The following standards are in use:

DIN EN 55022
DIN EN 61000-6-1: 2002-08
DIN EN 61000-6-2: 2002-08
DIN EN 61000-6-3: 2002-08
DIN EN 61000-6-4: 2002-08



Iserlohn, 15.10.2004 Dipl.-Ing. Klaus M. Schulte
(Ort, Datum) Geschäftsführer/Managing Director